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ASSESSMENT OF GENETIC DIVERSITY IN SAFFLOWER (*Carthamus tinctorius* L.) GERMPLASMS

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ABSTRACT

A quantum assessment of genetic divergence for fifteen quantitative characters among 150 accessions of safflower (*Carthamus tinctorius* L) representing different geographical areas by Mahalanobis D^2 statistical showed that there is a substantial genetic diversity. The D^2 values of accessions ranged between 10.90 to 84.32. The intra cluster distances were ranged from 18.94 to 30.87. These accessions were grouped into 24 clusters the clustering pattern necessarily associated with geographical diversity in the set of germplasm. Among the plant attributes biological yield, harvest index, plant height, volume weight, number of seeds per capitulum and capitula per plant were found to be important in the present study.

KEYWORDS: Safflower, D^2 Analysis, Genetic Divergence, Adaptation, Germplasm

INTRODUCTION

Safflower (*Carthamus tinctorius* L.) is one of oldest oilseed crop belongs to the family Asteraceae. It has multipurpose crop being grown over 60 countries in the world. India is the largest producer of safflower with 54 % area and 40 % production in the world. In India, It is cultivated in an area of 1.5 lakh ha with a production of 1.13 lakh tons giving a productivity of 726 kg/ha. Maharashtra and Karnataka are the first and second with reference to area and production, respectively whereas, productivity is highest in West Bengal (1000 kg/ha) followed by Bihar (805 kg/ha) and Karnataka (719 kg/ha) (Indiastat, 2014).

The assessment of the genetic diversity in crop species is of interest for the conservation of genetic resources, broadening of the genetic base and practical applications in breeding programs. Safflower possesses considerable diversity across different regions of the world (Knowles, 1989). In order to design an appropriate breeding program, it is important to know how much the phenotypic variation of a trait is heritable (Kearsey and Pooni, 1996), since the efficiency of a selection program is mainly dependent on the magnitude of genetic variation and heritability of a trait (Falconer and Mackay, 1996). Genetic diversity of a crop species has been investigated using either agro-morphological traits or molecular markers.

Genetic diversity is of considerable practical interest in any crop improvement programme. Precise information on the nature and degree of genetic divergence would help the plant breeder in choosing the right type of parents for different breeding programmes. Therefore, the present investigation was undertaken to study the nature and magnitude of genetic divergence in 150 germplasm accessions of safflower.

MATERIALS AND METHODS

Hundred and fifty germplasm accessions obtained from different parts of India and seven checks of safflower (*Carthamus tinctorius* L.) were selected for study. These accessions and checks were sown in the experimental area of Agriculture Research Station, Annigeri, Karnataka, India during *rabi* season 2011-2012, with spacing between rows was 45 cm and the distance between plants was 20 cm. Data were analyzed using Windostat software version 9.1. A recommended package of practice was followed to raise healthy crop under natural conditions.

Observations on yield and yield related traits viz., plant height (cm), rosette period (days), days to 50 % flowering, days to maturity, capitula per plant, capitulum diameter (cm), number of seeds per capitulum, floret weight (g), test weight (g), volume weight (g), oil content (%), hull content (%), biological yield (g), harvest index (%), seed yield per plant (g). The observations were recorded on five randomly selected plants for each accession. The genetic divergence was worked out by using Mahalanobis D^2 statistics as described by Rao (1952). On the basis of D^2 values the genotypes were grouped into different clusters by employing Tocher's method as out lined by Rao (1952).

RESULTS AND DISCUSSIONS

Group Constellations

A method suggested by Tocher (Rao, 1952) was used to group the accessions in to different clusters based on D^2 values. The set of 150 accessions grouped into twenty four clusters indicating the presence of appreciable amount of genetic diversity among the accessions under study. The distribution pattern in to various clusters is depicted in Table 1 & Fig.1. The maximum number of accessions (99) was grouped into Cluster I, followed by Cluster III with 17 accessions, Cluster VIII with 12 accessions and Cluster XVI with two accessions. Remaining twenty Clusters (II, IV, V, VI, VII, IX, X, XI, XII, XIII, XIV, XV, XVII, XVIII, XIX, XX, XXI, XXII, XXIII, XXIV) were solitary containing one accession each. The intra-cluster D^2 values ranged from 18.94 to 30.87 (Table 2). The average intra- cluster distance among the members of Cluster VIII was the maximum followed by among members of Cluster XVI. The inter-cluster D^2 values ranged widely with minimum value of 10.90 and maximum value of 84.32. Clusters XIII and XXII were strikingly diverse from the rest of the clusters. The divergence between these two clusters was high as evident from their high inter-cluster distance. The minimum inter-cluster D^2 value (10.90) was observed between Clusters IV and V, indicating a closer relationship between accessions of these two clusters. Selection of parents for hybridization from different clusters was performed on the basis of mean statistical distance as suggested by Bhat (1970).

Contribution of Characters towards Divergence

Among the fifteen characters studied, the most important character contributing to the divergence was biological yield, followed by harvest index, plant height, volume weight, number of seeds per capitulum, capitula per plant, hull percentage and rosette period (Table 3). These observations were accordance with earlier studies by Shivani *et al.* (2011) and Safavi *et al.* (2012). The above results implied that in order to select genetically diverse genotypes for hybridization the material should be screened for important traits like biological yield, harvest index, plant height, volume weight, number of seeds per capitulum and capitula per plant. It is then expected that desirable segregants can be isolated from planned crosses between diverse accessions for the above traits. Farthest and nearest clusters has been grouped based on the D^2 value (Table 4). Indicating that genetic divergence between the groups based on divergence value helps for predicting the future hybrid development programmes.

Analysis of Cluster means

It indicated substantial variation among clusters grouped according to D^2 analysis (Table 5). Based on the range of means it is possible to know the characters influencing divergence. In the accessions of the present study, Cluster XV recorded the first rank for the yield contributing traits *viz.*, plant height, capitulum diameter, number of seeds per capitulum and test weight. It indicates that combination of these traits is very important for the improvement of seed yield so accessions belonging to these clusters can be further used in genetic improvement. Similar results were reported by Ghongade and Navale (1995). Days to 50% flowering recorded the lowest mean in the Cluster VI. Rosette period was the shortest in the Clusters VI and XXII. Cluster XV had the highest mean value for capitulum diameter and number of seeds per capitulum. Oil content and volume weight were highest in Cluster IX. Biological yield and seed yield showed the highest values in Cluster XIII. The clusters with multiple accessions also had comparably higher values indicating the wide range of variability available in the germplasm collection. Such distribution has also been reported by Pourdad and Singh (2002) and Shivani *et al.* (2011). The well spread out accessions can be utilised in genetic improvement programmes. Cluster XV had highest plant height and low plant height was observed in the Clusters VI, XVIII, XVII and XXII while remaining clusters had moderate plant height indicating the wide range of genetic diversity available in the accessions.

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Table 1: Clustering Pattern of 150 Accessions of Safflower Based on D^2 Analysis in a Germplasm Collection of Safflower Accessions (*Carthamus Tinctorius* L.) At ARS, Annigeri During *Rabi* 2011-12

Cluster No.	Number of Accessions	Name of the Accessions
I	99	GMU3635, GMU 3703, GMU 3632, GMU 3634, GMU 3653, GMU 3769, GMU 3670, GMU 3708, GMU 3675, GMU 3726, GMU 3649, GMU 3639, GMU 3740, GMU 3652, GMU 3642, GMU 3698, GMU 3699, GMU 3691, GMU 3687, GMU 3790, GMU 3656, GMU 3702, GMU 3780, GMU 3794, GMU 3748, GMU 3694, GMU 3731, GMU 3676, GMU 3735, GMU 3661, GMU 3773, GMU 3776, GMU 3671, GMU 3729, GMU 3745, GMU 3798, GMU 3683, GMU 3727, GMU 3771, GMU 3743, GMU 3692, GMU 3723, GMU 3792, GMU 3659, GMU 3783, GMU 3693, GMU 3646, GMU 3754, GMU 3774, GMU 3689, GMU 3725, GMU 3797, GMU 3793, GMU 3772, GMU 3722, GMU 3651, GMU 3738, GMU 3704, GMU 3626, GMU 3628, GMU 3644, GMU 3762, GMU 3741, GMU 3761, GMU 3768, GMU 3747, GMU 3766, GMU 3636, GMU 3789, GMU 3775, GMU 3645, GMU 3777, GMU 3756, GMU 3690, sGMU 3633, GMU 3757, GMU 3764, GMU 3796, GMU 3685, GMU 3770, GMU 3791, GMU 3753, GMU 3648, GMU 3667, GMU 3650, GMU 3778, GMU 3647, GMU 3637, GMU 3720, GMU 3786, GMU 3781, GMU 3734, GMU 3625, GMU 3678, GMU 3736, GMU 3746, GMU 3668, GMU 3749
II	1	GMU 3696
III	17	GMU 3737, GMU 3782, GMU 3684, GMU 3787, GMU 3654, GMU 3744, GMU 3706, GMU 3623, GMU 3679, GMU 3759, GMU 3640, GMU 3700, GMU 3701, GMU 3674, GMU 3711, GMU 3713, GMU 3760
IV	1	GMU 3673
V	1	GMU 3624
VI	1	GMU 3621
VII	1	GMU 3682
VIII	12	GMU 3638, GMU 3662, GMU 3672, EC 523367, GMU 3663, GMU 3739, GMU 3658, GMU 3680, GMU 3752, GMU 3721, GMU 3666, GMU 3705

Cont

Table 1

Cluster no.	Number of Accessions	Name of the Accessions
IX	1	GMU 3643
X	1	GMU 3718
XI	1	GMU 3686
XII	1	GMU 3765
XIII	1	GMU 3719
XIV	1	GMU 3677
XV	1	GMU 3715
XVI	2	GMU 3664, EC 523373
XVII	1	GMU 3750
XVIII	1	GMU 3709
XIX	1	GMU 3730
XX	1	GMU 3716
XXI	1	GMU 3641
XXII	1	GMU 3733
XXIII	1	GMU 3660
XXIV	1	GMU 3681

Table 2: Average Intra-Cluster and Inter-Cluster D^2 Values of 24 Clusters in Safflower Accessions at ARS, Annigeri during *Rabi* 2011-12

Clusters	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI	XXII	XXIII	XXIV
I	24.09	32.47	34.19	28.47	30.05	31.67	29.96	34.06	31.27	31.59	28.61	32.74	51.39	38.7	41.56	45.91	37.31	31.35	35.14	35.74	50.61	41.16	43.93	46.36
II		0.00	25.02	38.33	38.20	38.90	36.44	44.16	44.14	47.47	42.17	47.35	26.54	61.35	44.98	66.46	53.67	28.25	40.00	42.69	33.81	61.18	29.31	32.62
III			26.13	43.67	45.36	46.53	40.41	45.78	46.47	41.33	41.16	43.55	34.59	58.5	35.96	59.29	51.62	33.91	37.07	38.30	35.25	61.64	32.35	33.89
IV				0.00	10.90	19.10	11.84	26.41	30.12	43.9	35.13	34.20	55.91	33.63	47.10	49.73	46.05	38.18	33.22	37.46	61.37	43.57	52.26	53.43
V					0.00	12.62	17.89	26.13	33.22	44.66	36.38	37.13	57.08	37.39	51.19	51.55	49.82	38.47	36.56	43.45	64.99	43.54	53.31	53.37
VI						0.00	24.58	27.58	37.62	42.47	35.72	41.51	59.81	41.63	54.88	52.85	52.34	41.87	42.85	47.99	67.65	41.98	55.77	52.33
VII							0.00	26.80	31.52	44.32	35.09	32.91	51.00	38.89	39.74	50.94	51.18	41.23	27.65	31.98	58.09	51.16	47.63	50.54
VIII								30.87	37.57	41.09	38.77	37.96	59.90	40.71	46.87	49.16	52.21	44.05	38.04	42.82	66.39	48.39	56.33	54.78
IX									0.00	40.84	33.40	35.84	63.55	35.69	50.79	51.47	35.11	40.66	43.20	39.24	59.88	40.38	55.27	67.50
X										0.00	22.09	32.13	65.18	37.32	41.45	30.51	35.89	46.01	42.69	38.62	59.79	35.74	53.05	50.84
XI											0.00	23.82	61.38	33.67	40.68	33.43	37.23	45.42	35.77	31.25	57.36	35.06	44.88	51.58
XII												0.00	59.51	30.68	31.39	29.07	42.01	44.50	20.92	24.47	59.72	45.88	45.27	54.76
XIII													0.00	79.19	46.91	80.71	72.33	44.02	45.11	49.97	30.88	84.32	31.89	33.96
XIV														0.00	53.19	28.97	34.32	51.99	43.85	43.24	75.40	28.49	66.98	70.16
XV															0.00	46.63	58.29	48.75	21.24	26.30	49.03	67.71	35.91	43.17
XVI																18.94	45.06	60.64	43.54	43.18	77.06	41.15	65.45	65.97
XVII																	0.00	44.15	53.67	45.31	58.80	29.08	63.17	67.53
XVIII																		0.00	41.75	49.76	46.62	53.71	39.68	45.57
XIX																			0.00	23.32	52.20	60.24	36.09	44.12
XX																				0.00	46.29	56.1	43.37	50.15
XXI																					0.00	77.39	36.43	43.57
XXII																						0.00	72.57	72.55
XXIII																							0.00	35.71
XXIV																								0.00

Table 3: Per cent Contribution of 15 Characters towards Divergence in Safflower Germplasm Accessions

Sl. No.	Characters	Times Ranked 1st	Contribution %
1	Plant height (cm)	1103	9.87
2	Rosette period (days)	149	1.33
3	Days to fifty percent flowering	110	0.98
4	Days to maturity	86	0.77
5	Capitula per plant	476	4.26
6	Capitulum diameter (cm)	00	0.00
7	Number of seeds per capitulum	723	6.47
8	Floret weight (g)	00	0.00
9	Test weight (g)	00	0.00
10	Volume weight (g)	771	6.90
11	Oil content (%)	2	0.02
12	Hull percentage	426	3.81
13	Biological yield (g)	4633	41.46
14	Harvest index (%)	2693	24.10
15	Seed yield/ plant (g)	3	0.03

Table 4: Nearest Cluster and Farthest Cluster from Each other Based on D^2 Values in 150 Safflower Accessions at ARS, Annigeri During *Rabi* 2011-12

Cluster Number	Nearest Cluster	Farthest Cluster
I	IV (28.47)	XIII (51.39)
II	III(25.02)	XVI (66.46)
III	II (25.02)	XXII (61.64)
IV	V (10.90)	XXI (61.37)
V	IV (10.09)	XXI (64.99)

Table 4: cond.,		
VI	V (12.62)	XXI (67.65)
V`II	IV (11.84)	XXI (58.09)
VIII	V (26.13)	XXI (66.39)
IX	IV (30.12)	XXIV (67.50)
X	XI (22.09)	XIII (65.18)
XI	X (22.09)	XIII (61.38)
XII	XIX (20.92)	XXI (59.72)
XIII	II (26.54)	XXII (84.32)
XIV	XX11(23.49)	XIII (79.49)
XV	XIX (21.24)	XXII (67.71)
XVI	XIV (28.97)	XXI (77.06)
XVII	XXII (29.08)	XIII (72.33)
XVIII	II (28.25)	XVI (60.64)
XIX	XV (21.24)	XXII (60.24)
XX	IX (23.32)	XXII (56.10)
XXI	XIII (30.88)	XXII (77.39)
XXII	XIV (28.49)	XIII (84.32)
XXIII	II (29.31)	XXII (72.57)
XXIV	XIII (33.96)	XXII (72.50)

Table 5: Cluster Means for 15 Quantitative Characters in a Germplasm Collection of 150 Safflower Accessions Evaluated at ARS, Annigeri During *Rabi* 2011-12

	PH	RP	DFF	DM	CPP	CD	NSPC	FW	TW	VW	OC	HP	BY	HI	SYPP
I	59.48	31.37	72.82	132.90	22.56	2.17	23.27	0.46	4.76	61.12	31.20	47.57	55.05	28.20	15.47
II	57.20	29.00	71.00	131.00	31.40	2.18	22.00	0.24	5.60	59.22	31.90	49.72	80.00	26.80	21.44
III	65.06	32.19	74.29	134.30	23.09	2.24	28.95	0.46	4.90	59.77	31.38	47.32	75.88	20.73	15.71
IV	65.60	32.00	72.00	133.00	25.40	1.84	15.40	0.19	4.75	63.95	29.92	48.20	50.00	46.12	23.06
V	59.40	29.00	73.00	133.00	27.80	1.92	19.40	0.19	4.40	60.25	34.63	48.58	50.00	49.28	24.64
VI	55.20	28.00	66.00	131.00	26.00	2.20	24.80	0.34	4.30	55.80	31.53	53.64	50.00	49.32	24.66
VII	72.20	33.00	75.00	135.00	25.80	2.18	19.60	0.33	5.80	66.52	30.61	53.38	55.00	44.54	24.50
VIII	63.50	31.42	73.75	133.80	19.88	2.22	30.04	0.44	4.61	63.99	31.88	49.32	50.00	44.97	22.27
IX	56.20	32.00	74.00	134.00	26.60	2.04	17.80	0.28	4.24	82.64	34.75	54.44	45.00	29.56	13.30
X	58.20	31.00	76.00	136.00	10.20	2.22	36.60	0.43	3.80	53.58	28.86	54.12	45.00	18.27	8.22
XI	59.60	35.00	78.00	138.00	24.60	2.08	24.60	0.40	3.90	53.50	28.45	63.12	45.00	23.23	10.45
XII	65.20	46.00	86.00	148.00	24.40	2.16	25.80	0.48	6.15	59.44	28.60	50.16	45.00	29.07	13.08
XIII	66.20	35.00	79.00	139.00	30.80	2.24	23.40	0.34	4.99	60.24	29.93	44.30	100.00	26.14	26.14
XIV	66.40	35.00	77.00	139.00	16.60	1.92	15.75	0.25	3.92	61.16	30.74	44.60	25.00	34.76	8.69
XV	84.40	46.00	86.00	143.00	21.20	2.46	36.80	0.42	6.03	60.85	31.20	49.44	65.00	22.02	14.31
XVI	67.60	43.50	84.50	145.00	10.40	2.38	31.40	0.51	3.83	47.83	30.89	49.24	27.50	25.18	7.01
XVII	51.00	33.00	73.00	133.00	11.20	1.80	7.80	0.36	5.13	65.94	30.28	41.86	40.00	11.95	4.78
XVIII	54.80	29.00	70.00	132.00	34.20	1.98	24.00	0.56	4.01	63.80	31.12	27.52	65.00	24.45	15.89
XIX	75.40	45.00	87.00	147.00	26.80	2.26	26.20	0.25	4.44	59.13	31.75	46.00	60.00	33.52	20.11
XX	73.40	46.00	87.00	143.00	14.60	2.18	17.40	0.42	6.59	64.54	27.01	58.38	60.00	25.52	15.31
XXI	65.66	35.00	76.00	136.00	21.80	1.26	11.60	0.48	5.55	63.46	30.58	48.10	95.00	8.13	7.72
XXII	46.20	28.00	68.00	128.00	14.40	1.88	15.00	0.53	6.08	54.15	31.65	50.52	25.00	27.42	6.86
XXIII	69.80	39.00	80.00	140.00	45.20	2.00	27.80	0.36	4.80	52.81	32.55	50.60	80.00	16.58	13.26
XXIV	70.80	30.00	74.00	134.00	21.60	2.40	32.00	0.32	4.45	34.81	28.09	44.70	85.00	25.25	21.46

PH: Plant height (cm) RP: Rosette period (days) DFF: Days to fifty percent flowering DM: Days to maturity

CPP: Capitula per plant CD: Capitulum diameter (cm) NSPC: Number of seeds per capitulum FW: Floret weight (g)

TW: Test weight (g) VW: Volume weight (g) OC: oil content (%) HP: Hull percentage

BY: Biological yield per plant (g) HI: Harvest index (%) SYPP: Seed yield per plant (g)

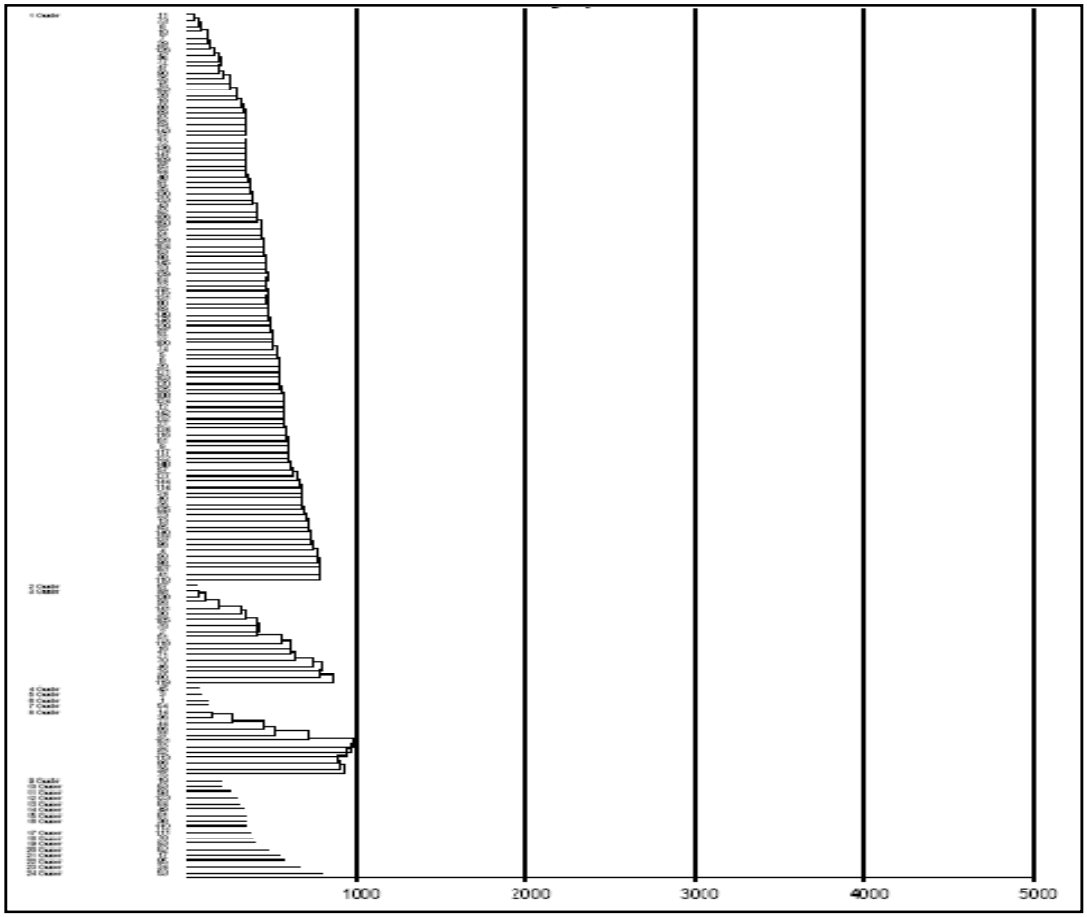

Figure 1: Dendrogram Showing Clustering of 150 Safflower Accessions by Tocher's Method